Texas A&M Transportation Institute
Proving Ground

Texas A&M Transportation Institute
3135 TAMU
College Station, TX 77843-3135

979-845-6375
Fax: 979-845-6107
http://tti.tamu.edu/crashtesting

TECHNICAL MEMORANDUM

Contract No.: **T4541-CN**
Test Report No.: **607911-3**
Project Name: ***MASH* Testing of Portable Concrete Barrier Pinned on Concrete Pavement**
Sponsor: **Roadside Safety Pooled Fund**

DATE: **May 16, 2017**

TO: **Jeffery K. Petterson, P.E.**
Washington Department of Transportation

COPY TO: Epifania Davila, TTI RDO
D. L. Bullard, Jr., Head, TTI Roadside Safety & Physical Security Division
Rebecca Heck, TTI Roadside Safety & Physical Security Division

FROM: **Nauman M. Sheikh**, P.E., Associate Research Engineer, TTI Roadside Safety & Physical Security Division

PREPARED BY: **Wanda L. Menges**, Research Specialist, TTI Proving Ground
Darrell L. Kuhn, Research Specialist, TTI Proving Ground

FOR MORE INFORMATION:

Name: Nauman M. Sheikh
Phone: 979-845-8955
Email: N-Sheikh@tti.tamu.edu

SUMMARY REPORT:

DISCLAIMER:

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Roadside Safety Pooled Fund, Texas A&M University System, or Texas A&M Transportation Institute (TTI). This report does not constitute a standard, specification, or regulation. In addition, the above listed company/agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The results reported herein apply only to the article being tested. The test was performed according to TTI Proving Ground quality procedures and according to American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*).

INTRODUCTION

The purpose of the testing reported herein was to assess the performance of the Pinned Portable Concrete Barrier (PCB) according to the safety-performance evaluation guidelines included in American Association of State Highway and Transportation Officials (AASHTO), *Manual for Assessing Safety Hardware* (*MASH*) (*1*). The crash test was performed in accordance with *MASH* Test 3-11, which involves a 2270P vehicle impacting the pinned PCB at a target impact speed and impact angle of 62 mi/h and 25 degrees, respectively.

This technical memo provides details of the pinned PCB, documentation of the crash test performed, the results, and the assessment of the performance of the pinned PCB according to *MASH* Test 3-11 criteria.

TEST ARTICLE DESIGN AND CONSTRUCTION

The overall length of the test installation was 100 ft-7 inches. The installation was comprised of eight 12 ft-6 inch long precast concrete F-shape barrier segments connected end-to-end. The F-shape segments were 32 inches tall, 24 inches wide at the base, and 9½ inches wide at the top. The barrier segments were set on the edge of 8-inch thick unreinforced concrete pavement. Two steel anchor pins were used to secure each of the segments to the pavement. The pins passed through slots cast into the segments near each end (no pin in the middle slot) and into 1¾-inch diameter holes drilled in the concrete pavement. An 18-inch deep × 12-inch wide excavation was made on the field side of barrier segments 1 through 7. Details of the segments, including steel reinforcement, can be found in Attachment A.

Adjacent precast barrier segments were connected using a pin and loop type connection. The barrier connection was comprised of two sets of three loops that extended from the ends of adjacent barrier segments. A connecting pin was inserted through the loops to establish the connection. When installed, the distance between the end faces of adjacent barrier segments was about 1 inch. Refer to Sheet 5 of 5 in Attachment A for details of the connection.

The anchor pins were 1½ inches in diameter × 21¼ inches long and had blunt ends. A 4-inch square × ½ inch thick plate washer with a 1⅝-inch diameter centered hole was positioned at a 95° angle and welded (¼-inch fillet) near the top of the anchor pin. Refer to Sheet 5 of 5 in Attachment A for details. Photographs of the installation are shown in Figures 1 through 3.

Figure 1. Pinned PCB before Test No. 607911-3.

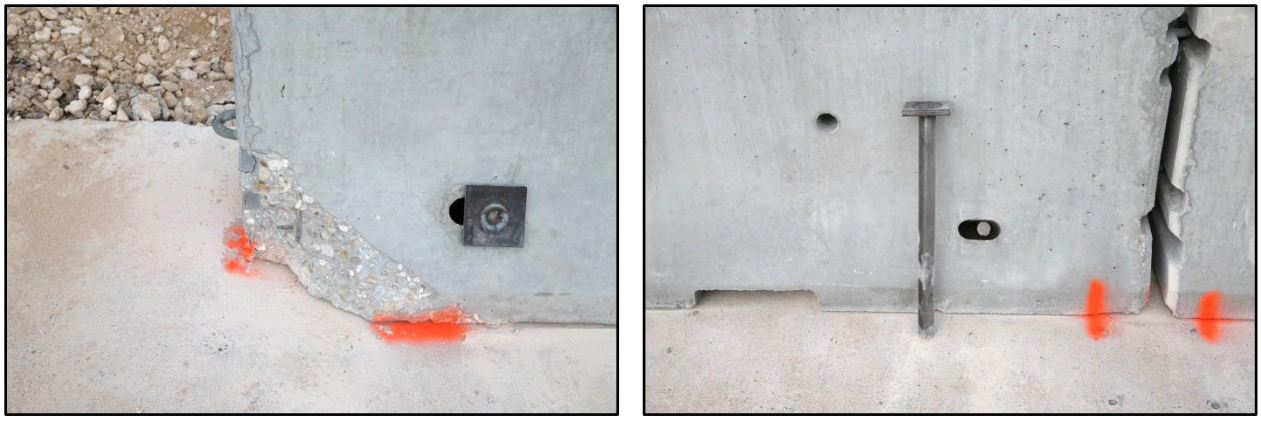


Figure 2. Anchor Pin for Test No. 607911-3.

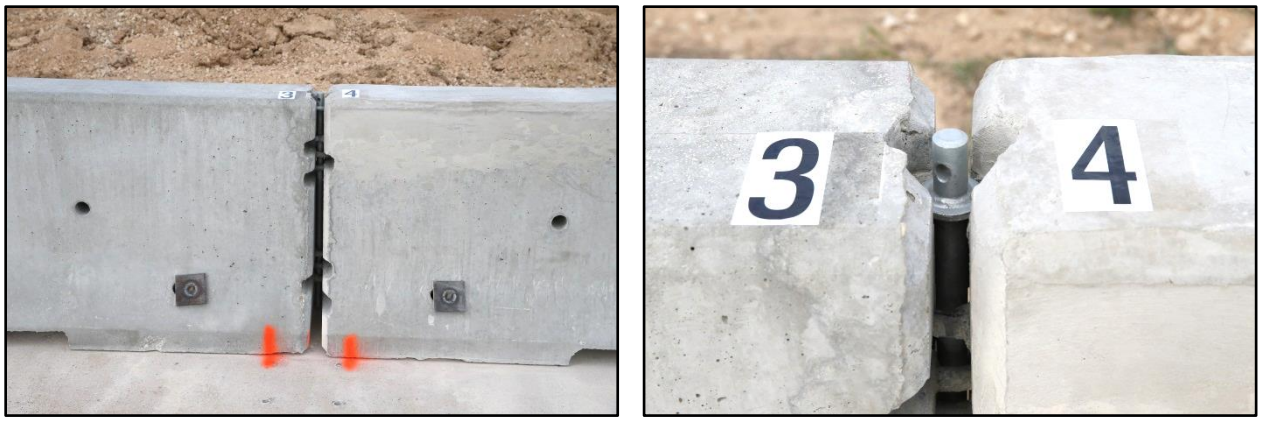


Figure 3. Connection for Test No. 607911-3.

The minimum compressive strength of the concrete for the precast F-shape barrier segments, provided by Waskey Bridges, Inc., was specified as 5000 psi. Cores were taken from the tops of segments 4 and 8 on Test No. 607911-1. The unconfined compressive strength of the concrete cores was 9150 psi and 4930 psi, respectively. The unconfined compressive strength of the concrete deck was 6975 psi and 7390 psi in front of segments 4 and 5, respectively.

All reinforcing steel was grade 60 material. The loops for the connecting pin were fabricated from ASTM A36 steel. The connecting pin between adjacent barrier segments was fabricated from ASTM A449 steel. The washer on each connecting pin met ASTM A572 grade 50 standards. The anchor pins (including the washers) met ASTM A36 specifications. Certifications for the materials used are on file at TTI Proving Ground.

TEST DESIGNATION AND ACTUAL TEST CONDITIONS

MASH test 3-11 involves a 2270P vehicle weighing 5000 lb ±100 lb, and impacting the barrier at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25 degrees ±1.5 degrees. The target impact point was 4.3 ft ± 1ft upstream of the joint between segments 3 and 4. The 2012 Dodge RAM 1500 pickup truck used in the test weighed 5047 lb and the actual impact speed and angle were 63.5 mi/h and 25.7 degrees, respectively. The actual impact point was 4.2 ft upstream of the joint between segments 3 and 4.

TEST VEHICLE

A 2012 Dodge RAM 1500 pickup truck was used for the crash test. Test inertia weight of the vehicle was 5047 lb, and its gross static weight was 5047 lb. The height to the lower edge

of the vehicle front bumper was 11.0 inches, and the height to the upper edge of the front bumper was 26.5 inches. The height to the center of gravity was 28.0 inches.

SOIL AND/OR WEATHER CONDITIONS

The crash test was performed the morning of March 22, 2017. Weather conditions at the time of testing were: Wind speed: 9 mi/h; wind direction: 190 degrees (vehicle was traveling in a northwesterly direction); temperature: 75°F; relative humidity: 70 percent.

BRIEF TEST DESCRIPTION

The 2012 Dodge RAM 1500 pickup truck, traveling at an impact speed of 63.5 mi/h, impacted the pinned PCB 4.2 ft upstream of the joint between segments 3 and 4 at an impact angle of 25.7 degrees. At 0.016 s after impact, segment 3 at the joint between segments 3 and 4 began to displace toward the field side, at 0.017 s, the left front tire began to climb the traffic face of segment 3. Segment 4 at the joint between segments 3 and 4 began to displace toward the field side at 0.032 s, and the concrete pavement began to crack under the joint between segments 3 and 4 at 0.034 s. At 0.035 s, the vehicle began to redirect and segment 4 at the joint between segments 4 and 5 began to rotate toward the traffic side. The field side toe on the upstream end of segment 3 began to crack at 0.058 s, and the right side tires were airborne at 0.099 s and 0.163 s, respectively. At 0.208 s, the vehicle was traveling parallel with the barrier, and at 0.263 s, the left rear exterior bed and rear bumper contacted the barrier. The vehicle lost contact with the barrier at 0.550 s, traveling at an exit speed and angle of 54.2 mi/h and 2.7 degrees. Brakes on the vehicle were not applied. The vehicle subsequently rolled 471 degrees counterclockwise, then 111 degrees clockwise, and came to rest upright 167 ft downstream of impact and 27 ft toward traffic lanes. Figure 4 show the barrier and test vehicle after Test No. 607911-3.

Figure 4. Pinned PCB and Test Vehicle after Test No. 607911-3.

TEST ARTICLE/COMPONENT DAMAGE

Figure 5 shows damage to the barrier. The upstream field side corner of segment 2, the upstream field side and downstream traffic side corner of segment 3, the downstream traffic side corner of segment 4, and the upstream field side corner of segment 6 were damaged. The anchor pins broke through the concrete pavement at segments 2 through 5, and the pavement was also cracked downstream of the upstream field side pin of segment 6.

Figure 5. Pinned PCB after Test No. 607911-3.

TEST VEHICLE DAMAGE

Figure 6 shows the damage sustained by the vehicle. The front bumper, hood, radiator and support, left front fender, left front tire and rim, left front door and window glass, left rear door, left rear exterior bed, left rear tire and rim, rear bumper, tailgate, rear springs, right rear exterior bed, right rear tire and rim, right front fender, right front tire and rim, right front ball joint, left frame rail, left upper and lower A-arms, and roof were damaged. Maximum exterior crush to the vehicle was 12.0 inches in the front plane at the left front corner at bumper height. Occupant compartment deformation was 2.0 inches in the kick panel/toe panel area.

Figure 6. Vehicle after Test No. 607911-3.

OCCUPANT RISK VALUES

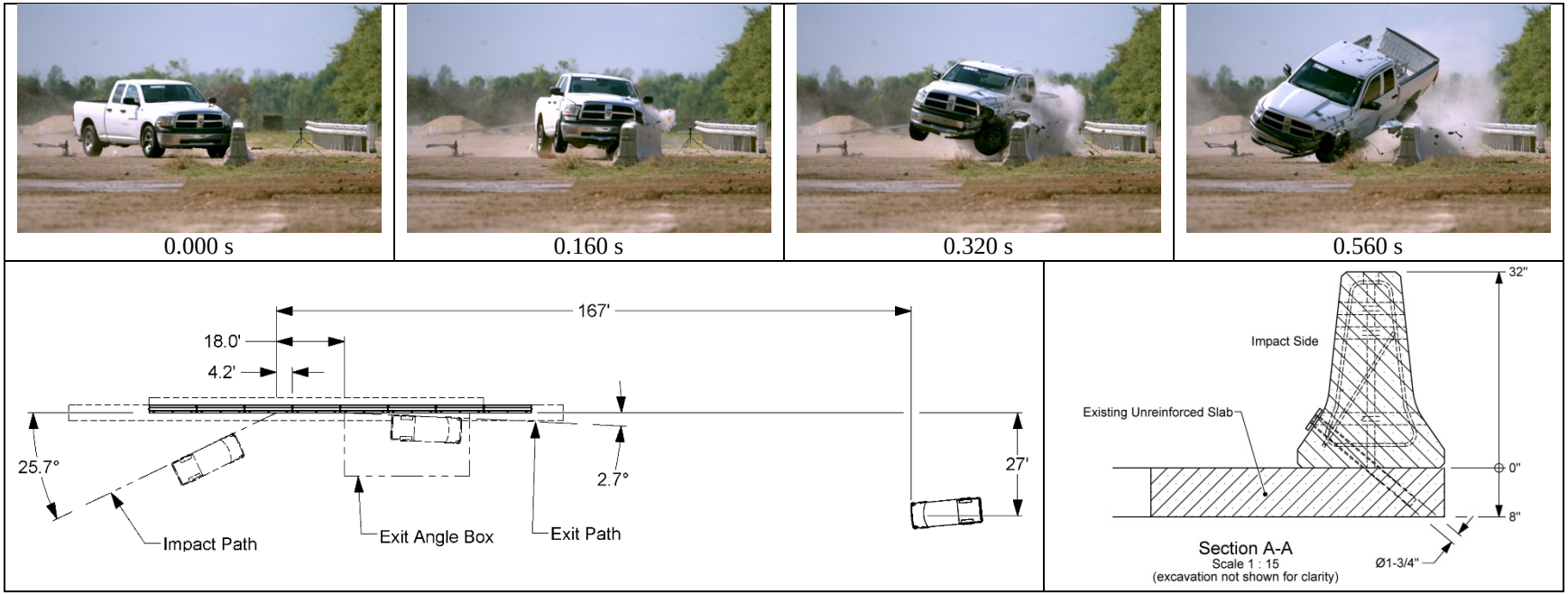
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity (OIV) was 13.8 ft/s at 0.110 s, the highest 0.010-s occupant ridedown acceleration was 5.6 g from 0.132 to 0.142 s, and the maximum 0.050-s average acceleration was −6.69 g between 0.014 and 0.064 s. In the lateral direction, the OIV was 19.0 ft/s at 0.110 s, the highest 0.010-s occupant ridedown acceleration was 16.3 g from 0.253 to 0.263 s, and the maximum 0.050-s average was 10.5 g between 0.035 and 0.085 s. Theoretical Head Impact Velocity (THIV) was 25.6 km/h or 7.1 m/s at 0.106 s; Post-Impact Head Decelerations (PHD) was 16.5 g between 0.253 and 0.263 s; and Acceleration Severity Index (ASI) was 1.38 between 0.056 and 0.106 s. These data and other pertinent information from the test are summarized in Figure 7.

SUMMARY AND CONCLUSIONS

As shown in Table 1, the pinned PCB did not perform acceptably for *MASH* Test 3-11 due to the rollover event.

REFERENCES

1. AASHTO. *Manual for Assessing Roadside Safety Hardware, Second Edition.* 2016, American Association of State Highway and Transportation Officials: Washington, D.C.



General Information
- Test Agency ..... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ..... MASH Test 3-11
- TTI Test No. 607911-3
- Date 2017-03-22

Test Article
- Type ..... Pinned Portable Concrete Barrier
- Name ..... Pinned PCB
- Installation Length ..... 100 ft-7 inches
- Material or Key Elements ..... Eight 12 ft-6 inch long precast concrete F-shape barrier segments, 32 inches tall, 24 inches wide at base, and 9½ inches wide at top, pinned to concrete pavement

Soil Type and Condition ..... Concrete deck, damp

Test Vehicle
- Type/Designation 2270P
- Make and Model ..... 2012 Dodge RAM 1500
- Curb ..... 4850 lb
- Test Inertial ..... 5047 lb
- Dummy ..... No dummy
- Gross Static ..... 5047 lb

Impact Conditions
- Speed ..... 63.5 mi/h
- Angle ..... 25.7 degrees
- Location/Orientation ..... 4.2 ft upstream of joint 3-4

Impact Severity ..... 128 kip-ft

Exit Conditions
- Speed ..... 54.2 mi/h
- Angle ..... 2.7 degrees

Occupant Risk Values
- Longitudinal OIV ..... 13.8 ft/s
- Lateral OIV ..... 19.0 ft/s
- Longitudinal Ridedown ..... 5.6 g
- Lateral Ridedown ..... 16.3 g
- THIV ..... 25.6 km/h
- PHD ..... 16.5 g
- ASI 1.38
- Max. 0.050-s Average
  - Longitudinal ..... −6.9 g
  - Lateral ..... 10.5 g
  - Vertical ..... −5.6 g

Post-Impact Trajectory
- Stopping Distance ..... 167 ft downstream
  27 ft toward traffic

Vehicle Stability
- Maximum Yaw Angle ..... 195 degrees
- Maximum Pitch Angle ..... 22 degrees
- Maximum Roll Angle ..... 472 degrees
- Vehicle Snagging ..... No
- Vehicle Pocketing ..... No

Test Article Deflections
- Dynamic ..... 31.4 inches
- Permanent ..... 31.0 inches
- Working Width ..... 59.3 inches

Vehicle Damage
- VDS ..... Rollover
- CDC ..... Rollover
- Max. Exterior Deformation ..... 12.0 inches
- OCDI LF0000000
- Max. Occupant Compartment Deformation ..... 2.0 inches

Figure 7. Summary of Results for *MASH* Test 3-11 on the Pinned PCB.

Table 1. Performance Evaluation Summary for *MASH* Test 3-11 on the Pinned PCB.

Test Agency: Texas A&M Transportation Institute Test No.: 607911-3 Test Date: 2017-03-22

***MASH* Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy		
A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable	The pinned PCB contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 31.4 inches.	Pass
Occupant Risk		
D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	The concrete pavement broke around several anchor pins in the impact area, however, there was not penetration or potential for penetration of the occupant compartment.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Occupant compartment deformation was 2.0 inches in the kick panel/toe panel area.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle rolled 472 degrees counter-clockwise and then 111 degrees clockwise and came to rest upright.	Fail
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal OIV was 13.8 ft/s , and lateral OIV was 19.0 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.	Maximum longitudinal occupant ridedown acceleration was 5.6 g, and maximum lateral occupant ridedown acceleration was 16.3 g.	Pass

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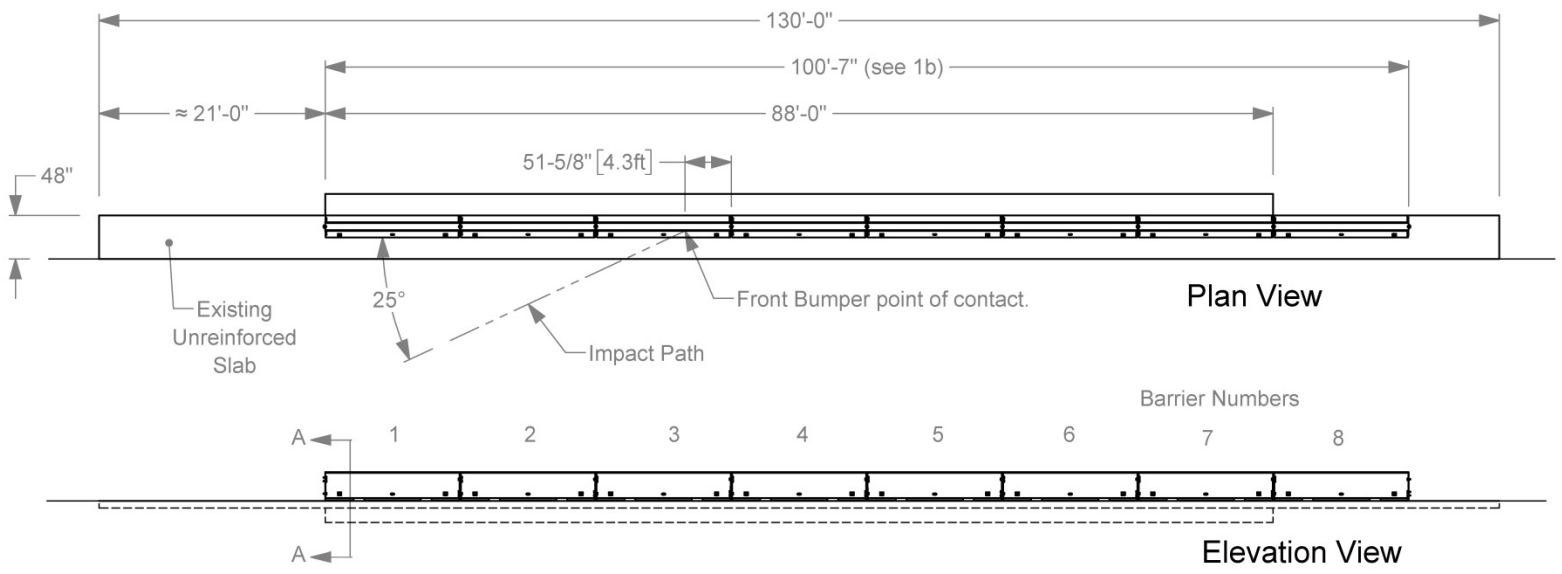
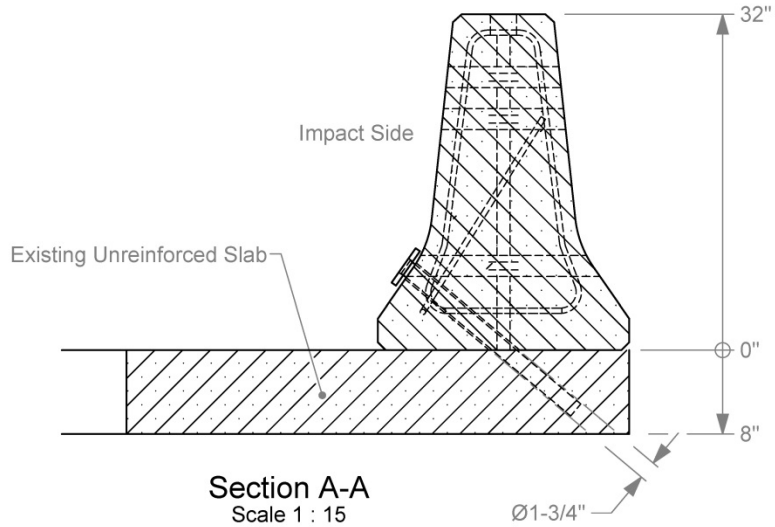
ATTACHMENT A: TEST ARTICLE DETAILS

Test Installation





Section A-A
Scale 1 : 15
(excavation not shown for clarity)

1a. Place the Barriers on existing un-reinforced concrete as shown, with the joints and centerlines of the Barriers aligned with anchor bolt locations from a previous installation. Connect the Barrriers with Connecting Pins (see sheet 5). Place two Anchor Pins in each Barrier; one in each outside slot. Drill Ø1-3/4" holes through the concrete deck, using the slots as a guide. Insert the pins and turn them so that the plate washers are as flat against the barriers as possible.

1b. Eight barriers at 12'6" with ≈1" space between barriers.

1c. Excavate behind the Barriers as shown, approximately 24" wide (backhoe bucket width), and minimum 18" deep.

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Project 607911-3	Pooled Fund Pinned Barriers		2017-03-03
Drawn By GES	Scale1:175	Sheet 1 of 5	Test Installation

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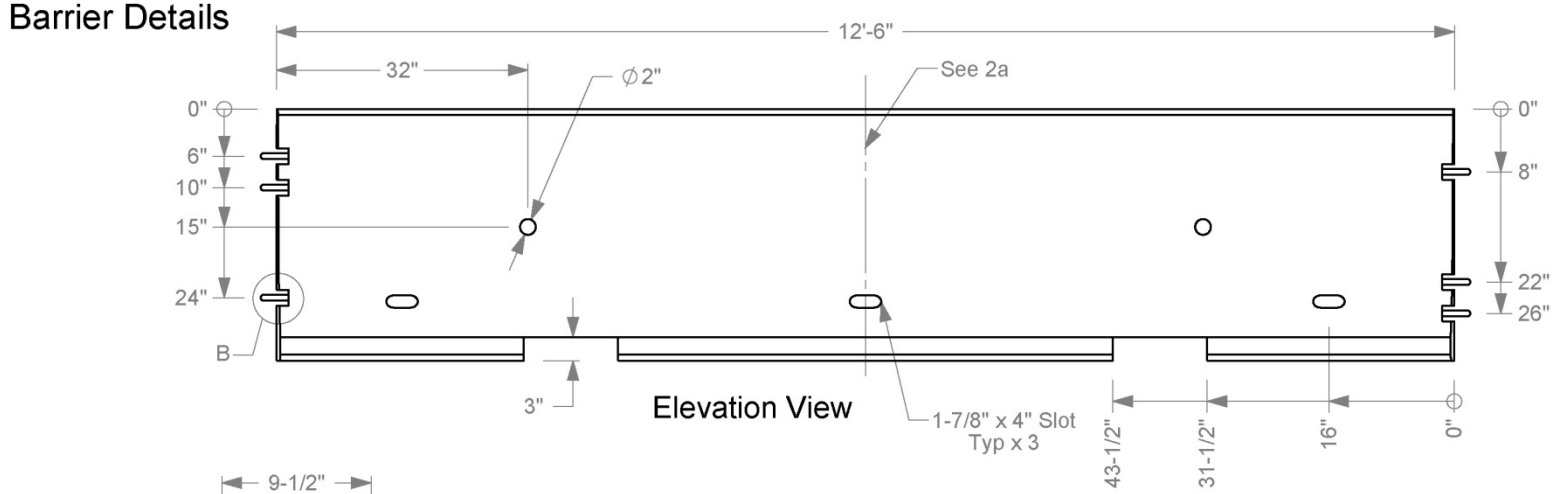
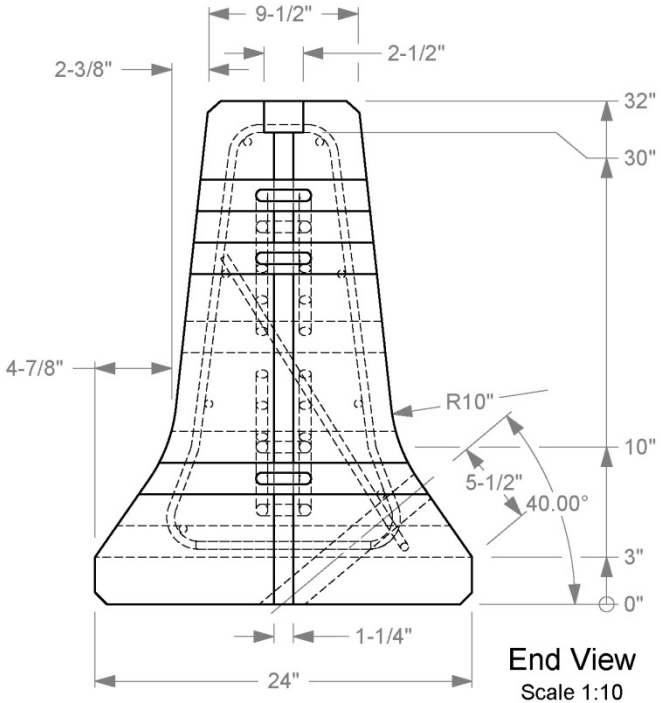
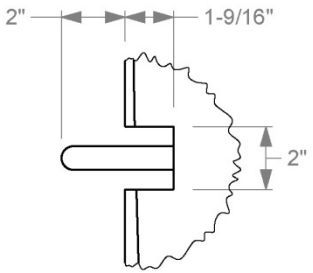
Barrier Details



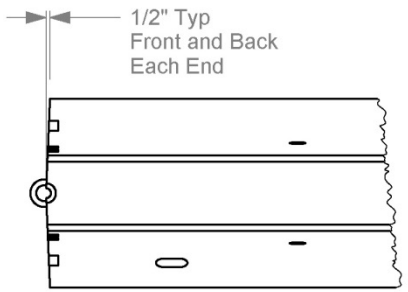
Elevation View



End View
Scale 1:10



Detail B
Scale 1 : 5
Typ all Loops



Plan View

2a. Barriers are symmetrical about ℄ 's, except for end loops. See next page for end loop and cut-out details.
2b. All rebar is grade 60.
2c. Concrete shall be 5000 psi.
2d. Chamfer top, bottom, and ends 3/4". End chamfers not shown for clarity.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project 607911-3	Pooled Fund Pinned Barriers		2017-05-02
Drawn By GES	Scale 1:20	Sheet 2 of 5	Barrier Details

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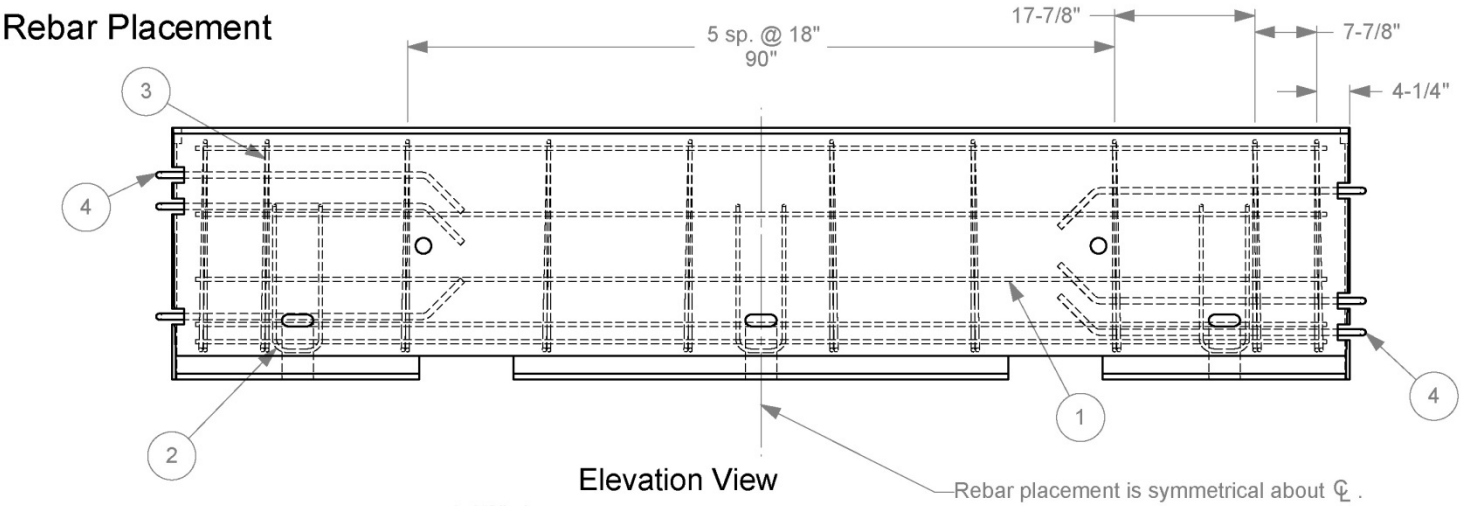
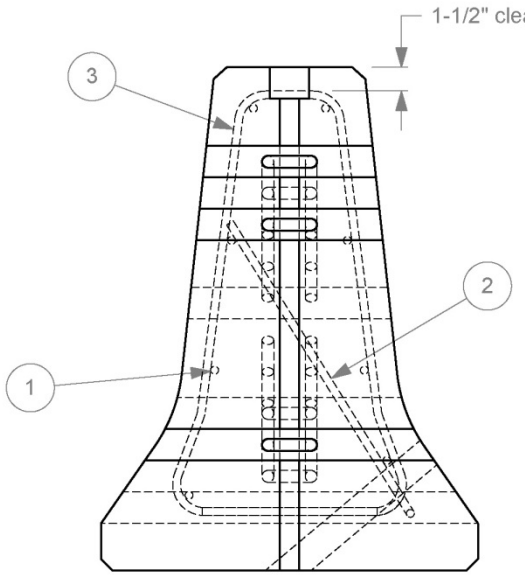
Rebar Placement



Elevation View

Rebar placement is symmetrical about ℄ .



End View
Scale 1:10

#	PART NAME	QTY.
1	Rebar, #4 x 144"	8
2	403 Bar	3
3	Stirrup	10
4	End Loops	6

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Project 607911-3	Pooled Fund Pinned Barriers	2017-05-02
Drawn By GES	Scale 1:20	Sheet 3 of 5 Rebar Placement

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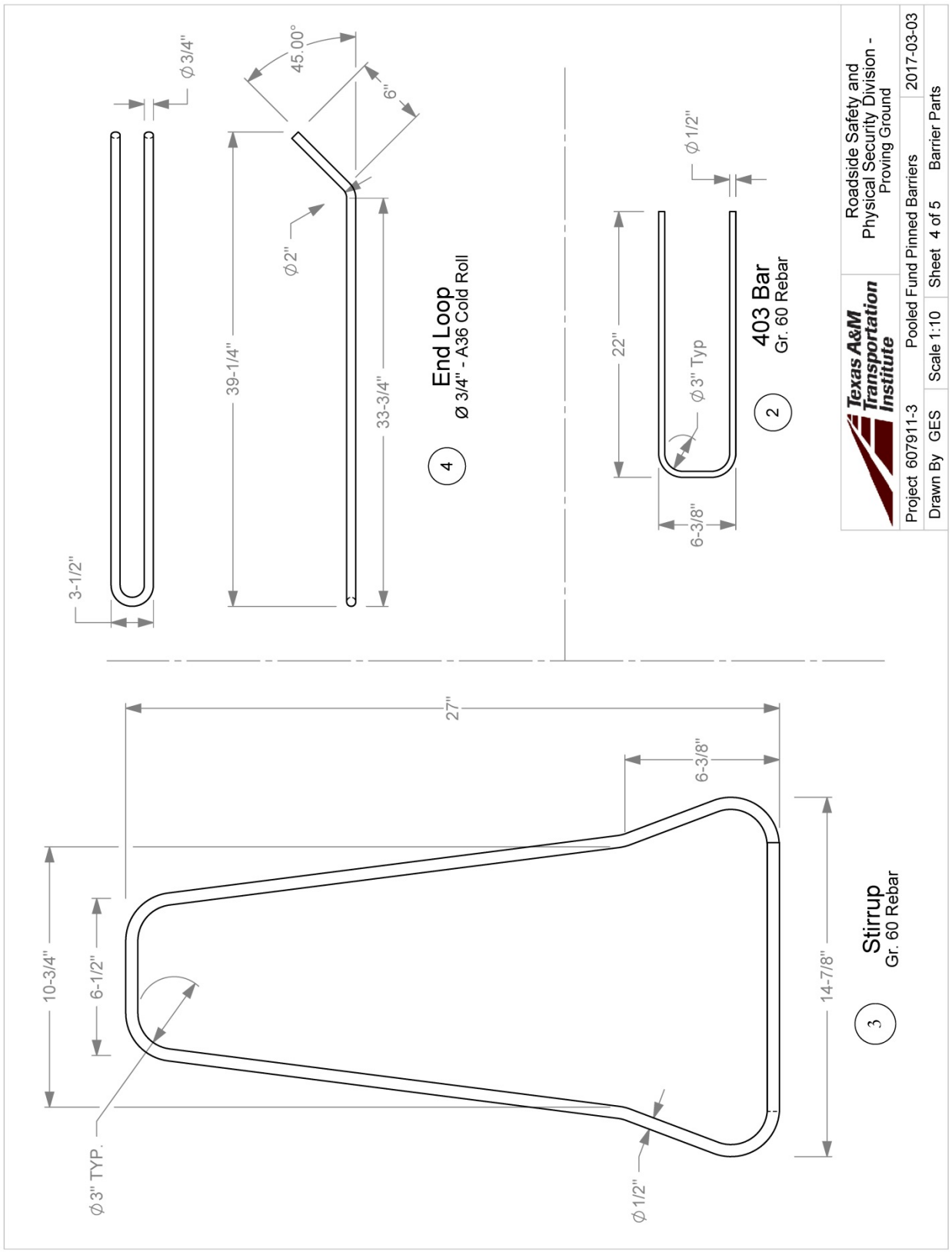
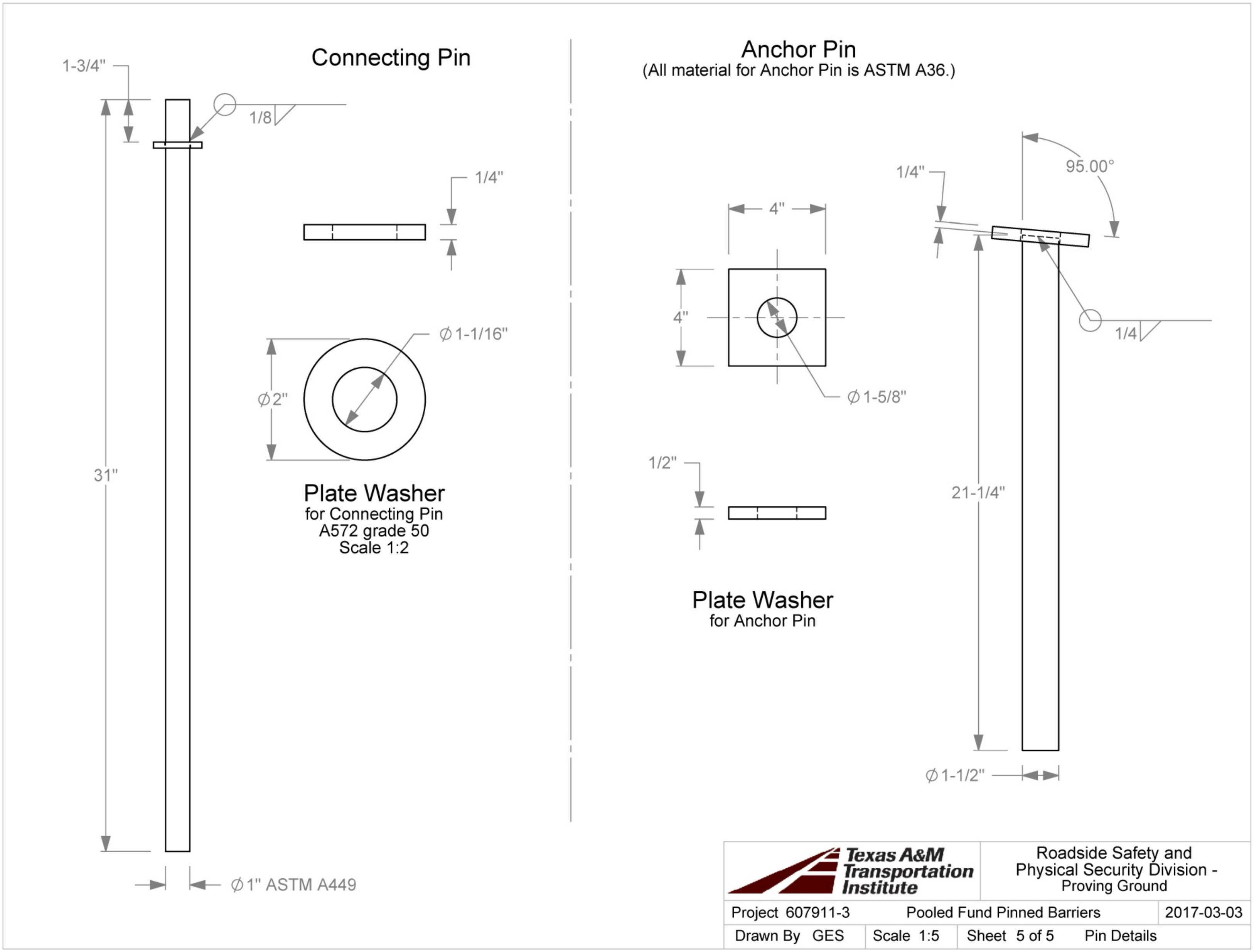

Roadside Safety and Physical Security Division - Proving Ground
Texas A&M Transportation Institute
Project 607911-3
Pooled Fund Pinned Barriers
2017-03-03
Drawn By GES
Scale 1:10
Sheet 4 of 5
Barrier Parts
3-1/2"
Ø3/4"
45.00°
6"
Ø2"
39-1/4"
33-3/4"
End Loop
Ø 3/4" - A36 Cold Roll
4
Ø1/2"
22"
Ø3" Typ
6-3/8"
403 Bar
Gr. 60 Rebar
2
27"
6-3/8"
10-3/4"
6-1/2"
Ø3" TYP.
Ø1/2"
14-7/8"
Stirrup
Gr. 60 Rebar
3



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